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Origin of Brackish Formational Ground Waters in the Pennsylvanian of New Brunswick

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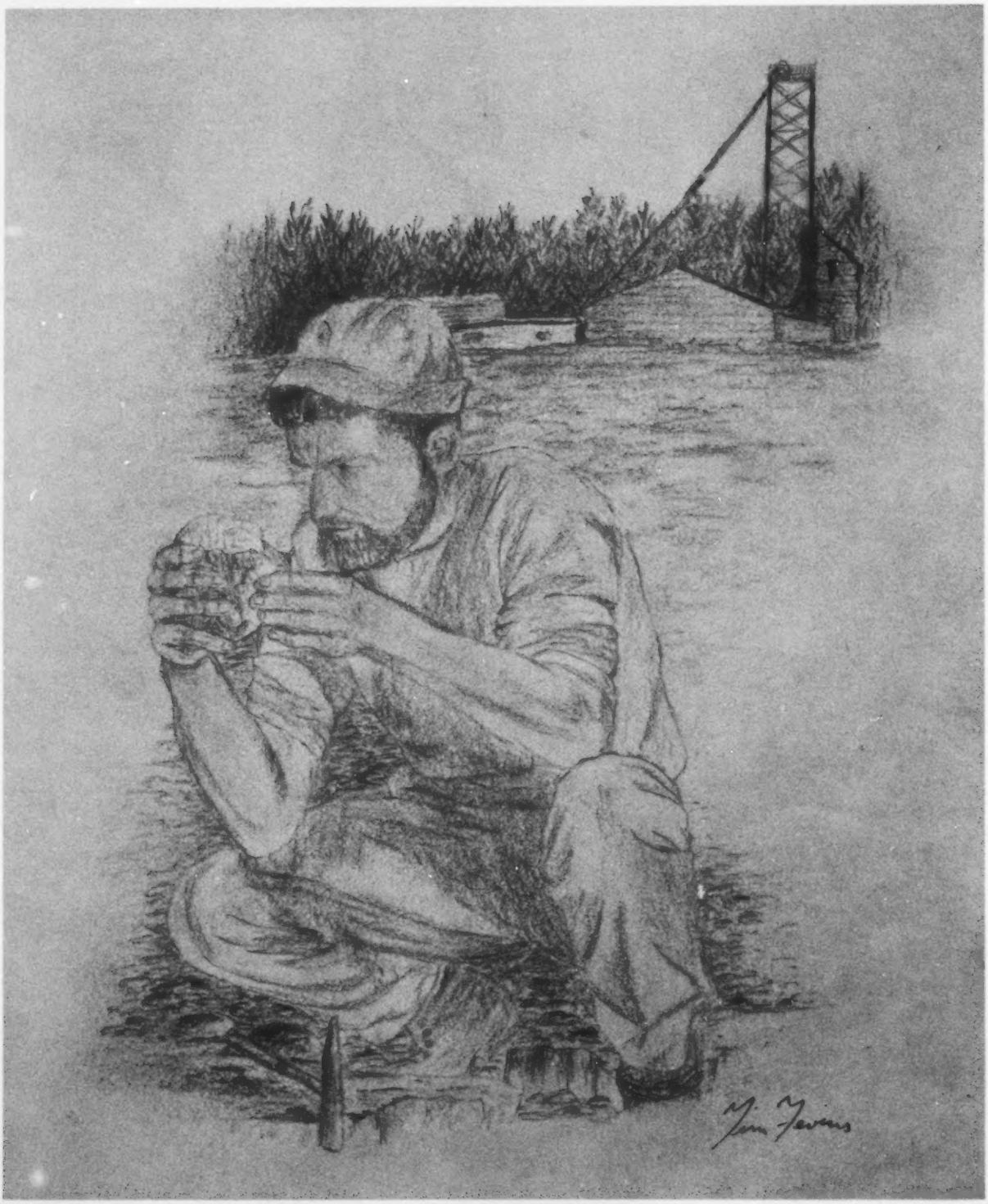

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ORIGIN OF BRACKISH FORMATIONAL GROUND WATERS IN THE PENNSYLVANIAN OF NEW BRUNSWICK

BY

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ABSTRACT

Thirty-nine (39) testholes drilled into Pennsylvanian strata during a recent drilling program have intersected brackish, formational groundwater with chloride concentrations exceeding 200 ppm. These wells do not appear to be a result of pollution and although some may be attributed to modern sea water incursion, the majority occur as far as 80 to 100 kilometers from the sea coast, in areas not known to be contaminated by any source of chloride.

A number of explanations for this anomalous, brackish water are considered: (1) subsurface evaporites in Pennsylvanian strata, (2) subsurface Mississippian evaporites, (3) weathering reactions within Pennsylvanian strata and (4) stagnant sea water, trapped in sediments since glacial times. Available information suggests the most likely explanation for these anomalous waters is the entrapment of sea water in regions of stagnant groundwater circulation since the late - Wisconsinan marine transgression which affected much of central and eastern New Brunswick.

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INTRODUCTION

It is well established that the Carboniferous of New Brunswick is represented by both Mississippian and Pennsylvanian strata. The former being well known for its indigenous potash-bearing evaporites while the latter contains significant deposits of coal. Rocks of both systems comprise almost 50 per cent of the Province's area and are largely restricted to three depositional basins (Figure 1): the New Brunswick Platform, the Moncton sub-basin and the Cumberland subbasin.

In recent years considerable effort has gone into assessing the potash potential of areas blanketed by Pennsylvanian clastics. Experience has shown that the recognition of numerous saline to brackish springs and wells in Carboniferous strata, particularly those showing anomalous concentrations of potassium, have played a significant role in the search for these important deposits.

The recent Carboniferous Drilling Project (Ball et al. 1981) has made some significant contributions in locating saline to brackish groundwater throughout New Brunswick. This project's primary objective was to evaluate the coal and mineral potential of the Province's Pennsylvanian strata through a program of shallow drilling. Towards achieving this objective, 294 testholes totalling 119,210.5 feet (36,335.6 metres) were drilled throughout the Province's three main Carboniferous basins. Detailed analysis of formational groundwater intersected during drilling was successful in locating 39 wells with

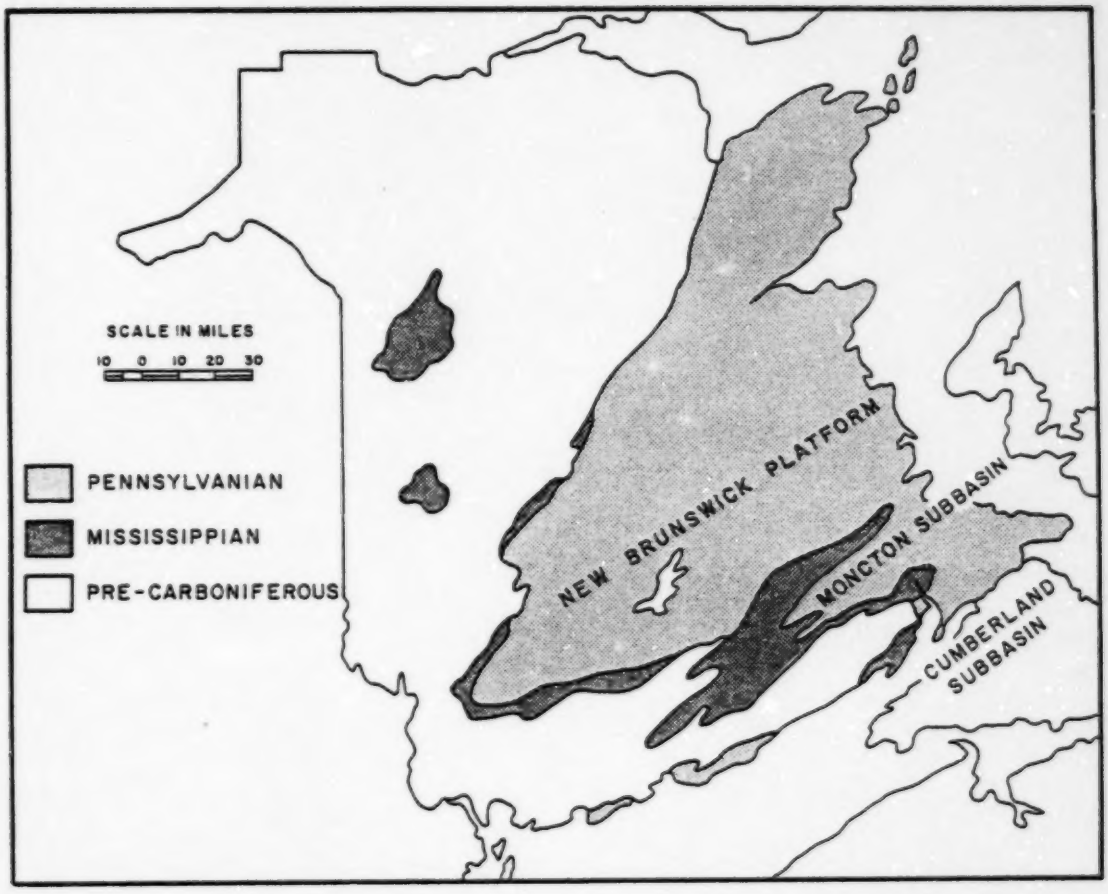

FIGURE 1 LOCATION OF NEW BRUNSWICK'S CARBONIFEROUS BASINS

anomalous chloride (Cl^-) ranging from 200 to 6700 parts per million (ppm). These wells do not appear to be affected by human contamination although some can probably be attributed to modern sea water incursion.

The purpose of this paper is to report on these unusual brackish wells and to suggest possible sources of the high chloride contents.

METHODS OF INVESTIGATION

The only well water data used in this investigation was that supplied by the Carboniferous Coal Drilling Project. Water samples were collected from 200- and 400- foot levels of all project testholes where possible. Several samples at intervals of approximately 200 feet were taken from deep testholes (1000 feet maximum). All samples were analysed by the groundwater laboratory of the Water Resources Branch for the following: conductivity, pH, alkalinity, hardness, Cl^-, K^+, Na^+, Mn^{++}, Ca^{++}, Mg^{++}, and $SO_4^=$. Sampling and analytical techniques followed are outlined in Supplementary Report No. 2 of the Carboniferous Coal Drilling Project entitled "Lithological and Formation Water Sampling" by Ball and Novaczek (1980).

The problem of determining the source of high Cl^- was found to require fairly extensive reconnaissance studies of regional geochemistry and regional geology. Groundwater samples from anomalous wells were analysed and compared with the chemistry of dilute sea water and saline waters known to originate from subsurface, Mississippian evaporite sources. Possible effects

of bedrock topography, lithology and structure were also considered.

DISTRIBUTION OF BRACKISH WELLS

All known brackish water wells in Pennsylvanian strata are located within 80 to 100 kilometers of the sea coast (Figure 2) and all occur below 90 metres elevation. A significant number of wells are found in and immediately adjacent to depressions in the bedrock surface or stream valleys.

POSSIBLE SOURCES OF CHLORIDE

Excluding those most likely to be related to incursion of present day sea water, four explanations for the existence of these inland brackish water wells are considered: (1) subsurface evaporites in Pennsylvanian strata, (2) subsurface evaporites in Mississippian strata, (3) complex weathering reactions within Pennsylvanian strata and (4) localized remnant sea water, trapped in sediments from glacial times when the area was inundated by the ocean.

Present geologic knowledge indicates that the possibility of finding indigenous evaporite deposits in the Pennsylvanian strata of New Brunswick is remote. These rocks represent fluviatile-lacustrine-deltaic environments (Hamilton, 1961) and the occurrence of coal deposits certainly precludes the existence of widespread aridity, a necessary prerequisite for extensive evaporite formation. On this basis, Hamilton (1961) concluded "that any economic quantity of salt that may be present within the Pennsylvanian would almost

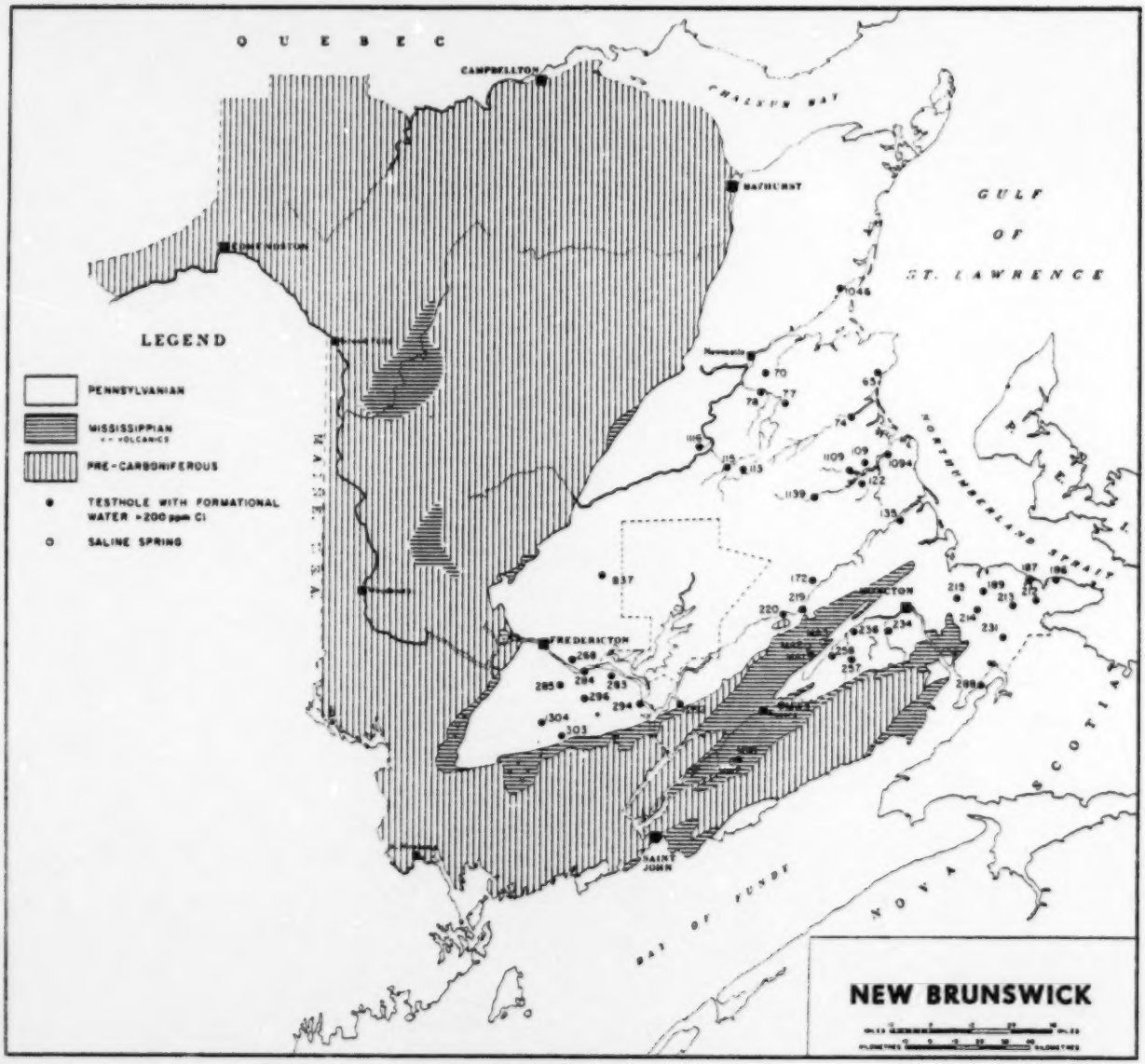

FIGURE 2 LOCATION OF INLAND BRACKISH WATER WELLS AND SALINE SPRINGS AND WELLS IN THE CARBONIFEROUS OF NEW BRUNSWICK

certainly have to have migrated there from underlying evaporite-bearing, Mississippian rocks".

For the most part, the character and distribution of Mississippian strata underlying Pennsylvanian cover in the Province is not precisely known, except locally. On the New Brunswick Platform, conglomerates and sandstones of possible Mississippian age have been found near Minto and Fredericton (Hamilton, 1961) indicating that some early Carboniferous sedimentation occurred on at least parts of the platform. Hamilton (1961) has noted that these presumed Mississippian clastics are generally overlain or capped by volcanics which probably protected them from pre-Pennsylvanian erosion. It is therefore highly possible that other areas of Mississippian strata, not protected from erosion were removed prior to or during Pennsylvanian deposition.

The findings of the Carboniferous Drilling Project and recent interpretation of aeromagnetic data (Spector, 1980) have limited the areas in which underlying Mississippian evaporite-bearing strata can be expected to occur. For example, the lack of Mississippian in the area of the Chipman/Canaan River pre-Carboniferous basement high would most certainly delete it from any future evaporite exploration (Ball et al, 1981). A similar lack of Mississippian has been noted in the St. Isidore, Bartibog, Rogersville, Coal Branch and Canaan Station areas.

In the Mississippian evaporite-bearing portions of the Moncton and Cumberland subbasins, experience has shown that most of these

deposits are associated with generally compact gravity lows and have been best preserved between basement "highs" or in down-faulted basinal structures. Regional reconnaissance over areas of Pennsylvanian cover involving gravity, seismic and aeromagnetic techniques have shown a significant lack of correlation in most cases between the location of most brackish wells and features considered as favourable indicators of subsurface evaporites (Figure 3).

A comparison of the water chemistry of brackish wells with those which are known to originate from Mississippian age evaporites (Windsor Group and Albert Formation) reveal significant differences (Tables 1 and 2). Total dissolved salts in most "Pennsylvanian" brackish wells are far below those of probable Mississippian sources. Major ions, considered diagnostic of most potash-bearing evaporites (K^+, Br^-, $SO_4^=$ and Cl^-) are lacking or occur in trace amounts in these anomalous waters. It is unlikely that such great discrepancies could be due to a simple case of fresh water dilution. Dilution of saline water with as much as 20,000 ppm Cl^- to a level typical of most of these waters would require groundwater circulating unobstructed throughout both unconsolidated and bedrock aquifers. With this in mind, it is important to note that most anomalous "Pennsylvanian" wells occur in areas underlain by thick, relatively impermeable shale (Figure 4). In such areas, relative stagnation would be expected to occur where groundwater is forced to migrate through available water-bearing fractures (i.e. joints, faults, and bedding planes). Coarser textured deposits

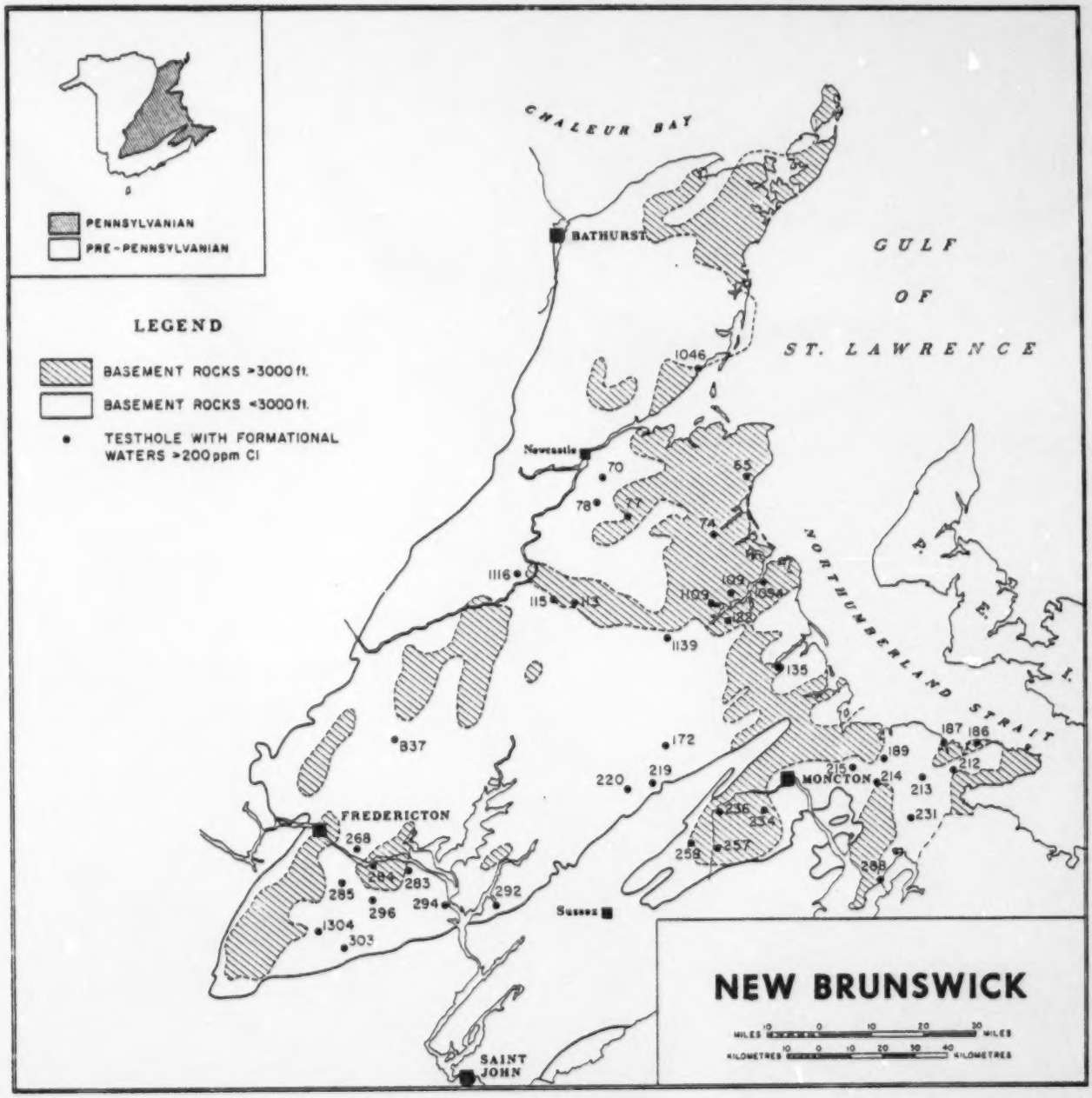

FIGURE 3 LOCATION OF BRACKISH WATER WELLS WITH RESPECT TO THE ESTIMATED DEPTH TO PRE-CARBONIFEROUS BASEMENT (SPECTOR, 1979 and 1980)

TABLE 1 WATER CHEMISTRY OF "PENNSYLVANIAN" BRACKISH WELLS

WELL NO.*	SAMPLE DEPTH	PPM Cl	Br	Mg	K	Na	Ca	SO_4	TDS**
65	380	260	-	-	7	230	-	-	-
70	400	1100	-	4.3	4	840	100	310	12,258
74	191	310	-	-	4	73	-	-	-
77	400	290	-	1.6	3	300	20	140	755
109	401	1000	-	13	3.6	1290	70	200	257
113	396	350	-	8	2	400	64	400	1,224
115	206	1200	-	8	4	900	250	1100	3,462
122	400	1700	-	8	6	1200	140	610	3,664
135	146	1700	-	61	4	580	390	-	-
172	401	760	-	3	2	485	85	-	-
186	400	340	-	10	2	170	81	23	626
187	400	530	-	7	4	200	51	17	809
189	200	430	-	3	7	210	11	16	677
212	400	200	-	5	4	110*	65	9	393
213	400	2800	-	2	10	570	26	41	3,449
214	400	460	-	1	5	300	29	4	799
215	200	1500	-	13	12	730	130	4	2,389
219	206	1000	-	43	3	560	24	-	1,630
220	191	4500	-	30	3	170	990	-	5,693
231	400	2700	-	12	-	1200	89	13	-
234	400	1100	-	2	4	370	160	140	1,776
236	400	2300	-	2.5	3	860	440	24	3,680
257	400	1600	-	6	4	620	460	660	3,350
258	400	4400	-	40	2	1760	1100	33	7,275
268	400	800	-	1	1	400	99	-	-
283	400	2800	-	8	14	1200	240	4	4,266
285	400	1200	-	1	2	450	35	4	1,692
288	360	220	-	3	5	180	19	16	443
292	400	460	-	-	2	180	-	10	-
294	400	1200	2	1	7	430*	17	220	1,875
296	400	240	-	1	3	210	10	30	494
303	400	320	-	1	8	170	22	270	791
1046	611	1600	-	41	17	1015	230	-	-
1094	1000	6700	61	40	13	2700	1000	520	10,973
1109	1000	2900	-	14	11	200	420	1100	4,695
1116	986	4500	1	1	9	2900	520	500	8,430
1139	1000	2600	-	18	9	1400	410	1100	5,537
1304	966	420	3	2	6	280	88	50	846
B37	400	230	-	1	2	280	21	7	541

*See Figure 2 for location

**Total dissolved salts less bromine

TABLE 2 WATER CHEMISTRY OF "MISSISSIPPIAN" SALINE WELLS AND SPRINGS

		PPM						
	WELL NO.*	Cl	Br	Mg	K	Na	Ca	SO_4	TDS**
WINDSOR GROUP	MW1	5600-9900	31-36	83-85	75-120	3400-3800	730-880	570-810	15,595
	MW2	13,000	45	80	160	5,500	700	-	20,440
	MW3	13,000	-	53	440	13,000	850	3000	30,343
ALBERT FORMATION	MA1	16,000	10	55	24	13,000	900	4300	34,279
	MA2	17,000	10	58	26	13,000	980	4300	35,364
	MA3	5100-7700	5	28-50	18	3800-5600	830	2100	16,298

*For location see Figure 2

**Total dissolved salts less bromine

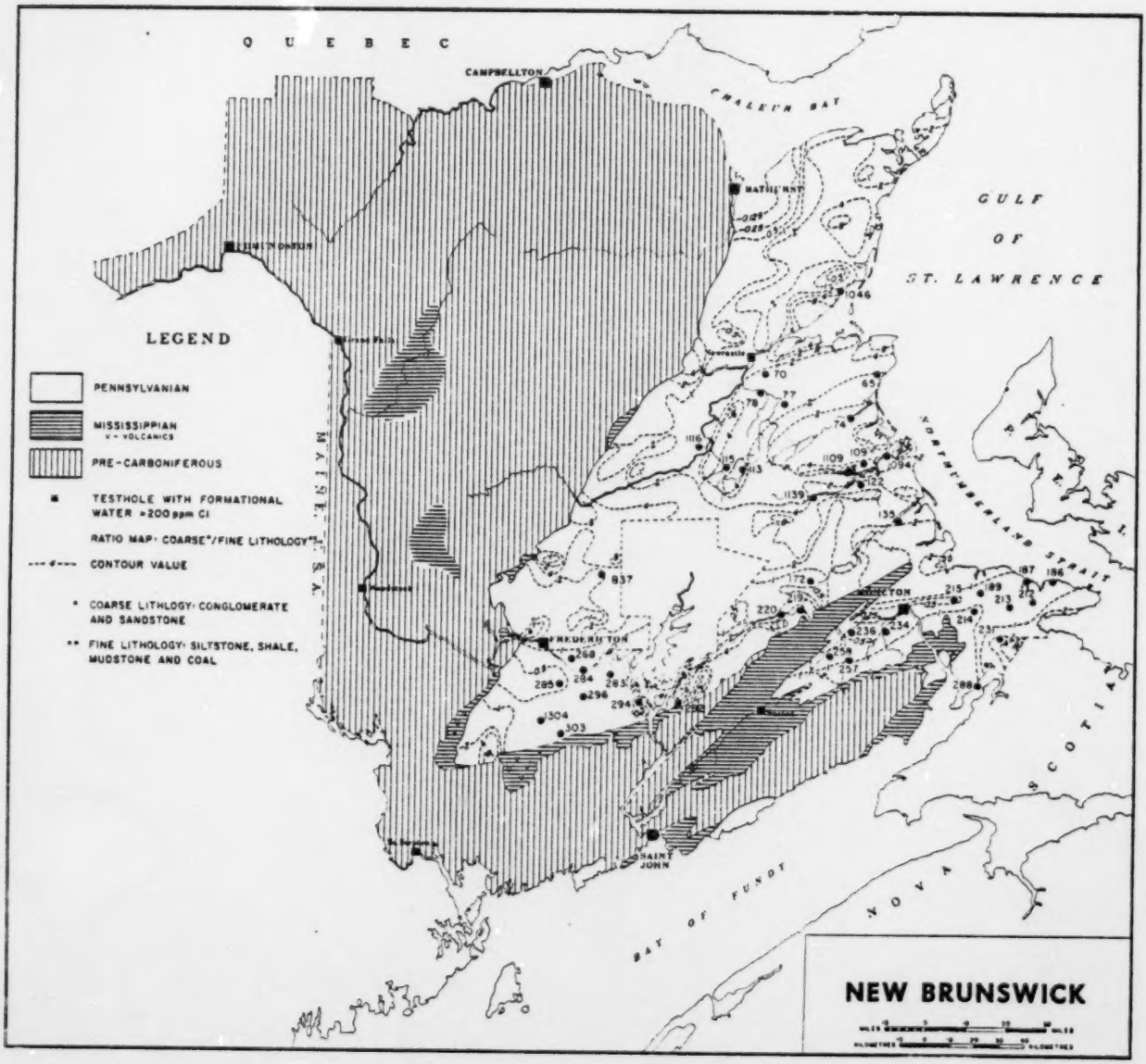

FIGURE 4 LOCATION OF INLAND BRACKISH WATER WELLS WITH RESPECT TO PENNSYLVANIAN BEDROCK LITHOLOGY (SULLIVAN, 1980)

isolated within these shaly units may also contain stagnant water. Anomalous wells near the present day sea coast, where the Pennsylvanian bedrock generally consists of more permeable, medium- to coarse-grained sandstone and conglomerate (i.e. Richibucto River area) (Figure 4) are expected to be largely a result of modern sea water incursion. The fact that most of these coastal wells are proximal to periglacial river valleys provides further corroborative evidence of this modern sea water influence.

On the basis of the above findings it would appear that a majority of the brackish waters are not of Mississippian origin, although this possibility should not be entirely dismissed.

Contributions of major cations and anions to groundwater through weathering reactions within Pennsylvanian clastics is probably minimal as it is unlikely that such a process could account for such high Cl^-, Na^+, K^+ and Ca^{++} concentrations in wells under investigation. This conclusion is based primarily on the following observations. First and foremost, Pennsylvanian clastics are for the most part mineralogically mature, consisting of a variety of weathered end products and accessory minerals (i.e. mica, illite, chlorite, sericite etc.). As a result, many of the original source constituents which are highly reactive to groundwater (i.e. Na-K-Ca plagioclases, metamorphic and igneous detritus) are not abundant enough to account for such high concentrations of Ca^{++}, K^+, Na^{++} and Cl^-.

Sea water entrapped in the sediments since the last glacial retreat is an additional explanation for the occurrence of these brackish

wells. Sea water, an obvious source of chloride, is considered to have transgressed over a substantial portion of central and eastern New Brunswick during the period of land submergence that followed the retreat of the last Wisconsinan ice margin, some 13,000 years ago (Rampton and Paradis, 1981). During this transgressive interval, sea water would have replaced fresh water contained in joints, fractures and in porous bedrock aquifers. The significant density contrast between sea water and fresh water accompanied by the greater volume and greater hydrostatic head would have also contributed significantly to this freshwater replacement.

With few exceptions, none of the brackish wells occur inland of the maximum limit of marine submergence, estimated at up to 90 metres above present day mean sea level throughout much of the Province (Figure 5) (Gauthier, 1978; Gadd, 1971; Rampton and Paradis, 1981; Thibault, personal communication; and Prest, et al. 1967). It is also interesting to note that most brackish wells are located in depressions or lows in the local bedrock surface (Figure 6). These areas were probably covered by deeper sea water and were therefore, most likely submerged longer than topographically higher areas resulting in more complete replacement of freshwater.

In order to further confirm the possible relict sea water origin for these brackish wells, age dating, based on tritium analysis was performed at University of Waterloo on selected samples from four anomalous wells. Results, indicate that most

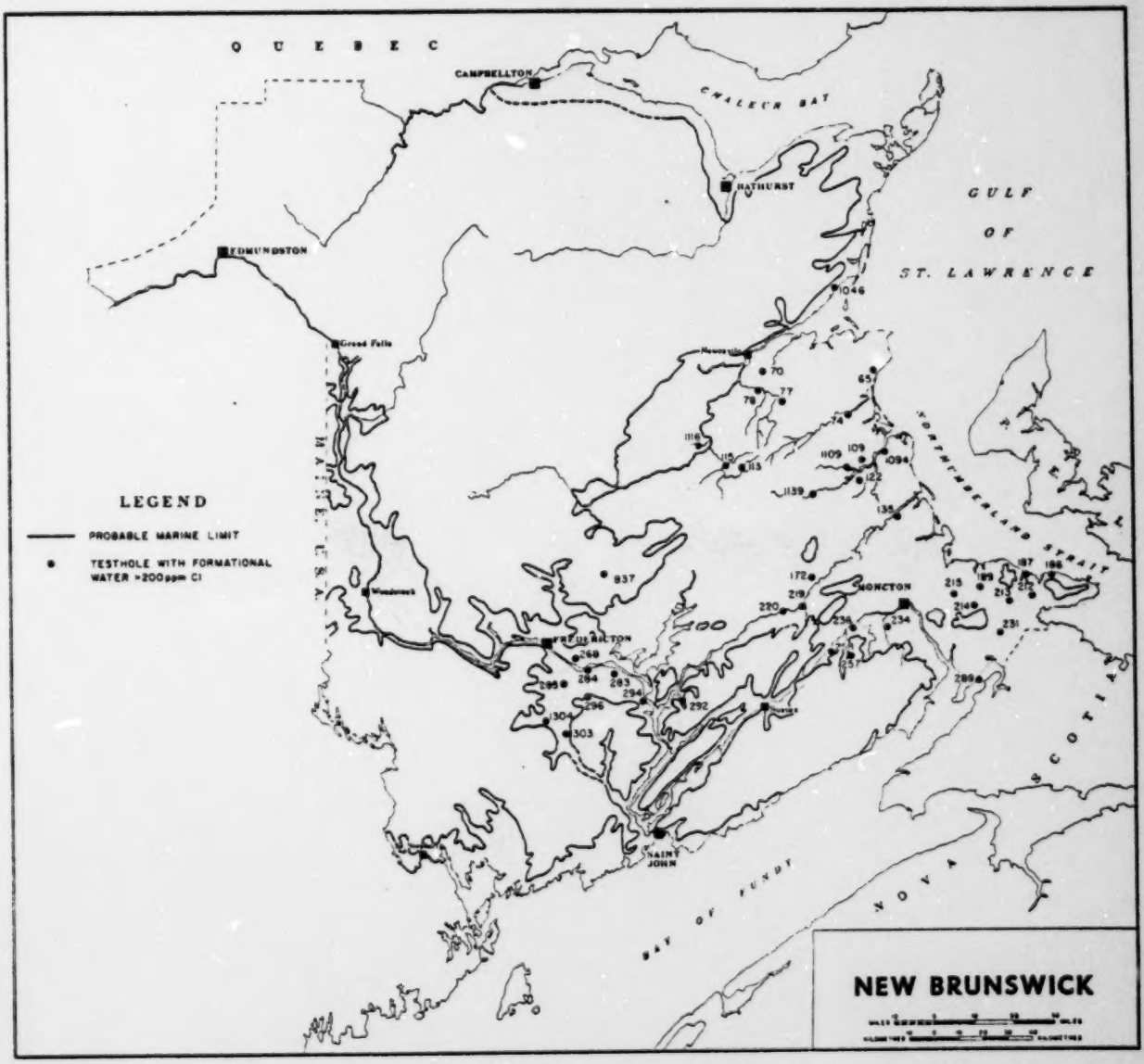

FIGURE 5 LOCATION OF INLAND BRACKISH WATER WELLS WITH RESPECT TO THE LATE-WISCONSINAN MARINE LIMIT (GADD, 1973; GAUTHIER, 1978; RAMPTON AND PARADIA, 1981 AND PREST, 1970)

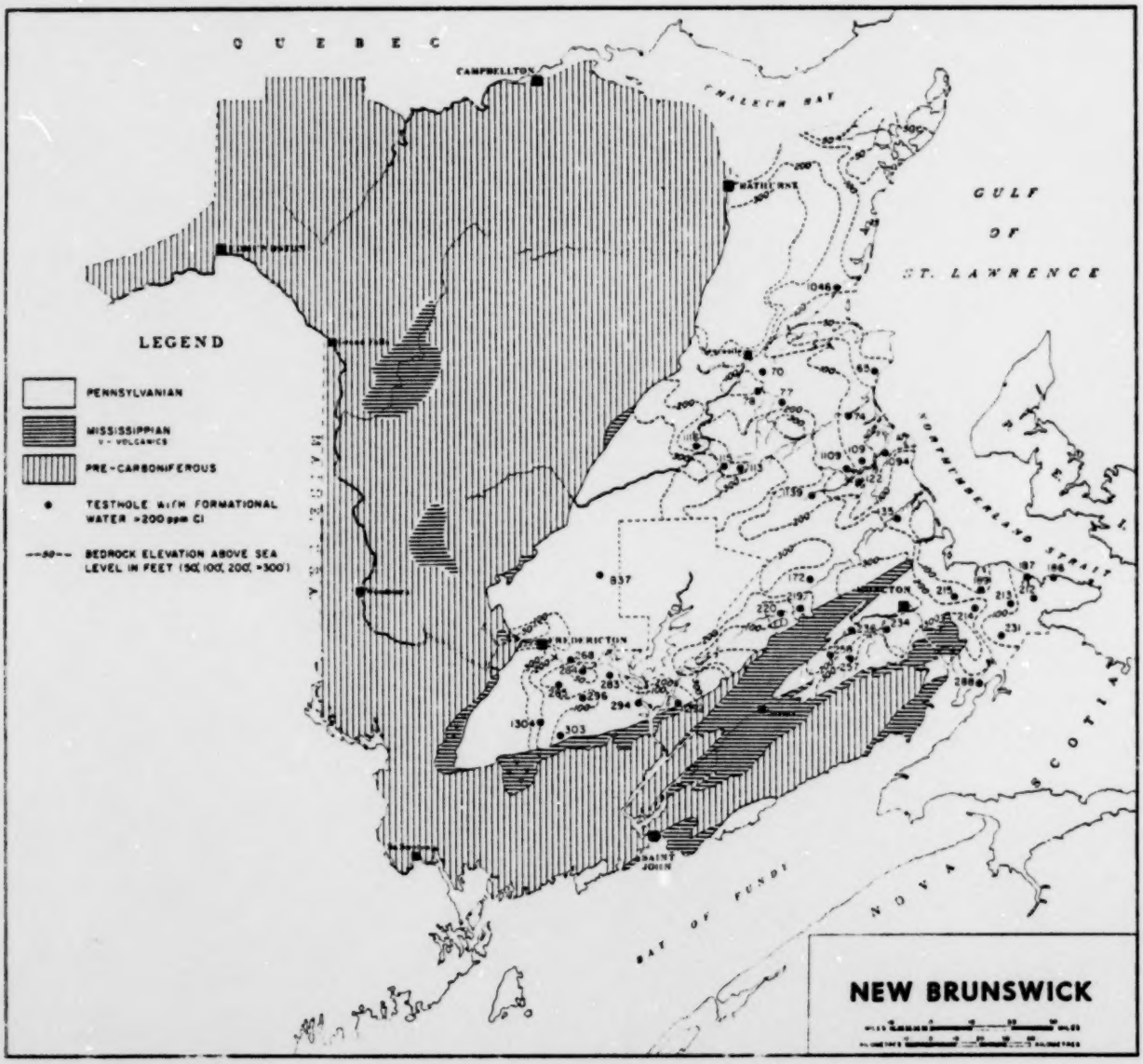

FIGURE 6 LOCATION OF INLAND BRACKISH WATER WELLS WITH RESPECT TO PENNSYLVANIAN BEDROCK TOPOGRAPHY (BALL, SULLIVAN AND PEACH, 1981)

well waters are probably a mixture of salt water and fresh water and therefore an accurate estimate of the age of the salt water component was not possible.

A comparison of various cation/chloride ratios of brackish well waters with, those predicted for dilute modern sea water from the open ocean revealed Ca^+ and Na^+ enrichment in most cases (Figure 7a and 7b) and Mg^+ and K^+ depletion (Figure 8a and 8b). These changes in element ratios with respect to modern dilute sea water may possibly reflect ion exchange and/or ion filtration in bedrock, particularly where clay minerals dominate the lithology (i.e. shale). The possibility also exists that the concentration ratios of the major ions in the original solution may have initially varied from those of the open ocean sea water. Conditions at the time of marine submergence were probably more estuarine than open ocean due largely to the fact that the sea, in all likelihood, transgressed in contact or in close proximity to the retreating ice margin (Tepper, 1980). Reactions with chemically unweathered glacial debris may have been partially responsible for enriching sea water in Na^+ and Ca^+ and depleting it with respect to Mg^+ and K^+. Sayles (1979) has demonstrated that diagenetic reactions at the sediment - sea water interface in the Atlantic Ocean has led to the uptake of Mg^+ and K^+ and the release of Ca^+, Na^+ and $HCO_3^=$ by the solid phases. These trends are consistent with those observed in most brackish Pennsylvanian well water samples.

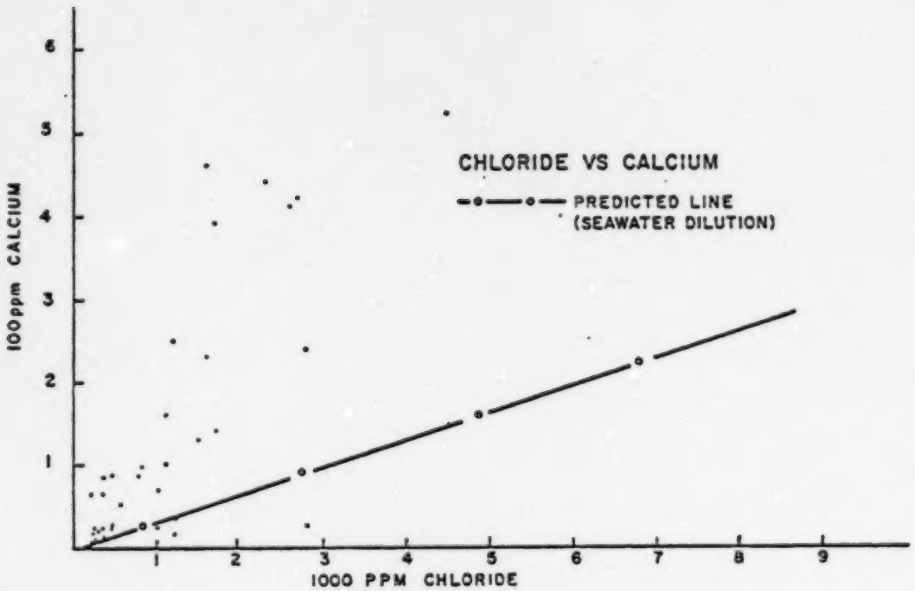

FIGURE 7A LINEAR RELATIONSHIP OF Ca AND Cl FOR BRACKISH WATER WELLS (JACKS, 1972 AND TEPPER, 1980)

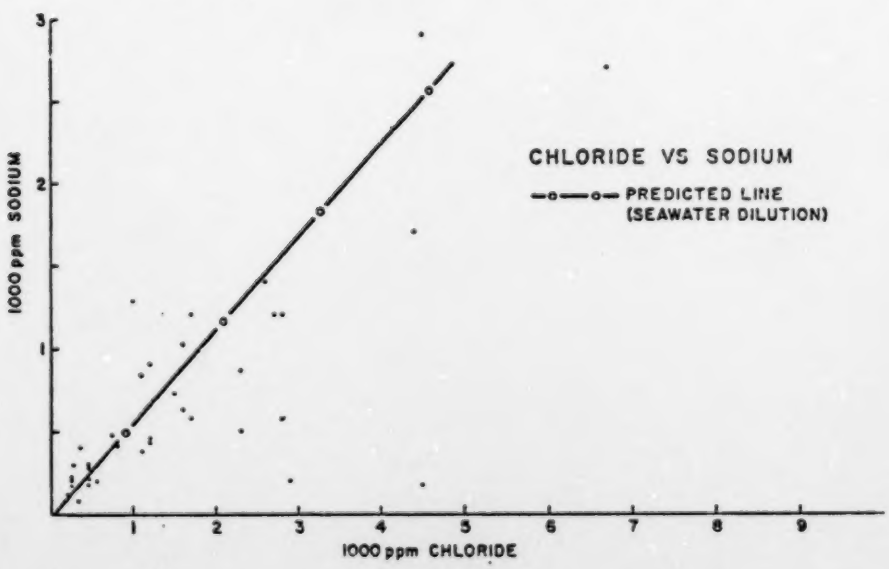

FIGURE 7B LINEAR RELATIONSHIP OF Na AND Cl FOR BRACKISH WATER WELLS (JACKS, 1972 AND TEPPER, 1980)

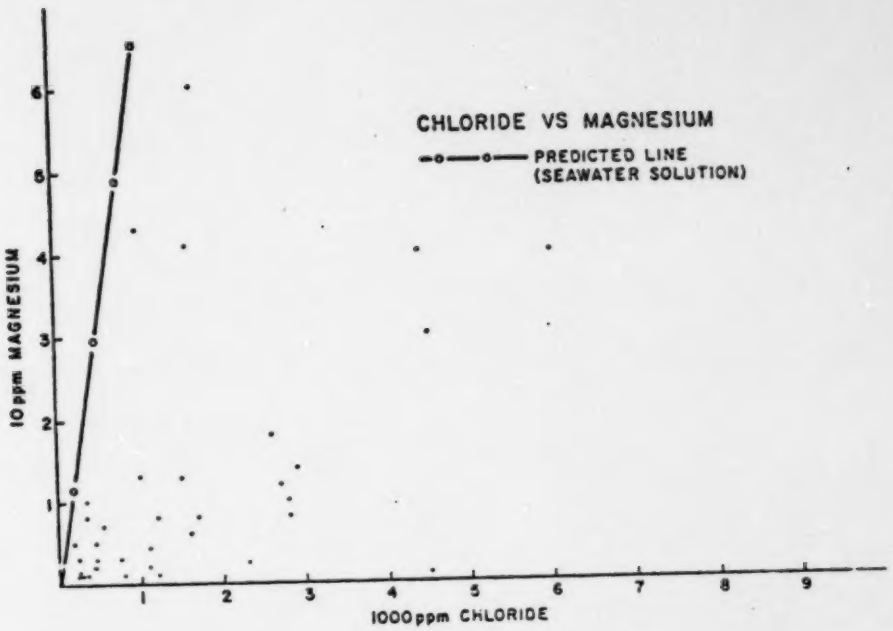

FIGURE 8A LINEAR RELATIONSHIP OF Mg AND Cl FOR BRACKISH WATER WELLS (JACKS, 1972 AND TEPPER, 1980)

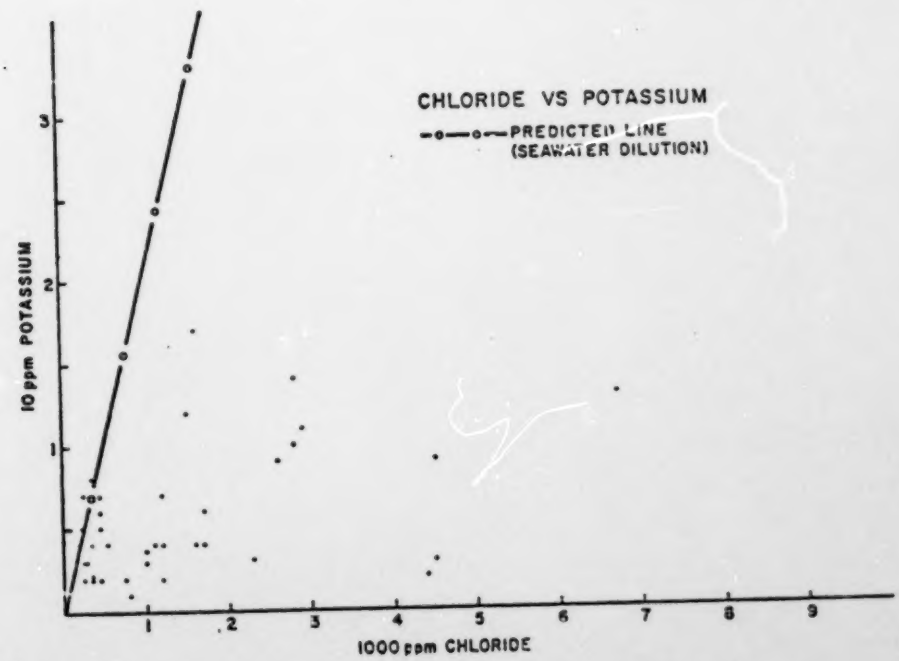

FIGURE 8B LINEAR RELATIONSHIP OF K AND Cl FOR BRACKISH WATER WELLS (JACKS, 1972 AND TEPPER, 1980)

CONCLUSIONS

Inland brackish groundwaters occur in Pennsylvanian clastics in central and eastern New Brunswick. Evidence for a subsurface evaporite source for the anomalously high chloride concentration in well waters is at present scant but the possibility must remain open, especially in areas of gravity lows and favourable basement structure. Other than those wells in which modern sea water incursion has occurred the most likely source of the high chloride is relict sea water, remaining from a marine transgression that followed the late - Wisconsinan ice sheet, some 13,000 years ago.

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